OPERATIONS CONSIDERATIONS IN DESIGNING A HIGH* SPEED MULTI CHANNEL DATA ACQUISITION SYSTEM

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Abstract

The increasing demand for more complex and sophisticated data acquisition systems in the Sandia fusion research program, along with high shot rates, requires that the systems be engineered to operate as efficiently, flexibly, and reliably as possible.

The Operations Research group, Division 1254, of Sandia Labs is now involved in the design of the DAS for PBFA-II. A DAS is needed that can meet the daily data acquisition needs of the facility. This system must remain flexible to meet the changing needs of the program without sacrificing reliability or accuracy.

Towards these ends, several unique features are being implemented in the PBFA-II DAS. Set up efficiency has been improved by a cable harness that easily allows any of over 700 signals to be cabled to more than 100 waveform channels. Flexibility has been increased by a trigger and fiducial patch panel switching system that quickly enables any of the 18 triggers and fidus to be connected to any of the waveform channels. Reliability has been improved by a specially designed cooling system and a modular system design approach.

Introduction

The PBFA II data acquisition system (DAS) will consist of 102 channels of waveform recorders and approximately 300 channels of single parameter measurements. This system will support a shot rate of one accelerator shot plus several timing shots per day. These different shots can require extensive reconfigurations of the DAS setup. In addition, any upgrades or modifications to the system must be done without decreasing the shot rate.

The system must be as reliable, efficient, and flexible as possible within the constraints of time, money and manpower, in order to support these objectives. These goals will be attained by using computer control whenever possible and providing manual functions in a logical manner. In addition, to minimize cost, the system will use readily available modular components. Finally, the system will be designed with the proper facilities support to minimize heat or power related failures.

These considerations were partially taken into account on previous systems; however, PBFA II will have the first DAS which incorporates previous operational experience during the design phase.

Early in the life of PBFA I, it was found that the DAS needed improvement. Numerous operator cabling errors, caused in part by crowded patching panels, led to lost time and data. The trigger and fiducial system inflexibility limited the configuration of of the transient digitizers. In addition, inadequate cooling caused a higher than expected rate of equipment failures. These problems were overcome by several system modifications and upgrades, which required more money, manpower, and down time. The valuable experience gained while establishing the operation of PBFA I is being incorporated into PBFA II through the use of these experienced operators during the design phase.

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Computer Control

Sandia has used computer controlled data acquisition systems on its large pulse power accelerators since 1976. This capability has been upgraded for the PBFA II DAS. The improvements [2] provide better computer controlled digitizer set up, calibration, arming, triggering, and data read out. Signal attenuation and some input signal switching is also done under computer control. This automation minimizes the possibility of operator error by checking that all digitizers are set up properly. However, there are still some manual functions which need to be performed during setup for data acquisition.

The major hardware improvement to the computer control of the system results from the use of a CAMAC based control module. Previous to this module's development only devices with IEEE 488 interfaces or TTL interfaces could be easily computer controlled. Relay driven devices requiring higher than TTL level source current (50-300mA) needed another interface to handle the required current and voltage. The interface that could handle 50-300mA source current at a variety of voltages is a CAMAC-based 48 bit open collector module. The CAMAC to IEEE 488 interface was familiar from use in the single point data systems, and the open collector circuit could be used with any external voltage supply up to 300mA per bit. The module is easily configured to provide TTL output levels. The module thus allowed computer control of a wider range of relay driven signal switches and programmable attenuators. As a result, higher bandwidth signal switches and programmable attenuators were incorporated in the PBFA II DAS. Additional computer-controlled switching and other devices can easily be added if needed.

Another improvement to the DAS is the inclusion of a prefire detection circuit to the performance monitoring and evaluation system (PMES). The system, which is similar to that of PBFA I [1], consists of approximately 300 channels of single parameter timing or amplitude digitizers for recording pulsed electrical diagnostics. LeCroy Model 4208 wide range timers are being used to monitor prefires. All signals which are subject to prefire have been combined into a single trigger source for these timers. In addition to triggering the timers, this fan-in circuit sends a pulse to the control/monitor system to indicate that a prefire has occurred and allow that system to take appropriate action. The long record length ($\pm$8.3 msec) of these timers allows determination of which accelerator unit prefired as compared to other units that were triggered by the prefire. In addition to monitoring accelerator signals, these timers will monitor the DAS trigger and fiducial generator's output. This data will correlate waveform data from different trigger sources and monitor the performance of these devices.

Although computer control is preferable, experience with previous systems shows that local manual control of all DAS hardware is essential. Troubleshooting or checkout of computer controlled hardware can be easily resolved as to software or hardware failure if the hardware can be operated manually. Further, a goal of our system is manual operation in a "worst case" fallback position.

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14. ABSTRACT

The increasing demand for more complex and sophisticated data acquisition systems in the Sandia fusion research program, along with high shot rates, requires that the systems be engineered to operate as efficiently, flexibly, and reliably as possible. The Operations Research group, Division 1254, of Sandia Labs is now involved in the design of the DAS for PBFA-II. A DAS is needed that can meet the daily data acquisition needs of the facility. This system must remain flexible to meet the changing needs of the program without sacrificing reliability or accuracy. Towards these ends, several unique features are being implemented in the PBFA-II DAS. Set up efficiency has been improved by a cable harness that easily allows any of over 700 signals to be cabled to more than 100 waveform channels. Flexibility has been increased by a trigger and fiducial patch panel switching system that quickly enables any of the 18 triggers and fidus to be connected to any of the waveform channels. Reliability has been improved by a specially designed cooling system and a modular system design approach.

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System Layout

One significant improvement of the PBFA II DAS is the signal cable patching from the 760 accelerator cables to the 102 waveform recorder inputs. Although the system provides input signal switching, a large number of manual patches still will be made for each shot. The input signal switching system consists of an array of four input, one output coaxial switches. Each switch output connects to one waveform recorder. One coax switch input is dedicated to the automatic calibration system. Another input is connected to the time domain reflectometer (TDR) panel (see Figure 1). The TDR panel allows an operator to verify cable connections and record signal cable lengths for all signal cables from one location. Previously a TDR was connected in the patching area by jumper cables. Cables were disconnected to allow insertion of the jumper cable. This method of measurement required the operator to measure cable lengths under difficult circumstances. The difficulty of this process sometimes resulted in broken pins in the jumper cable which were not detected until data was lost. The final two coaxial switch inputs are used for data signals. Each input allows the system to be connected to a different experiment. Switching from one to the other requires minutes rather than hours.

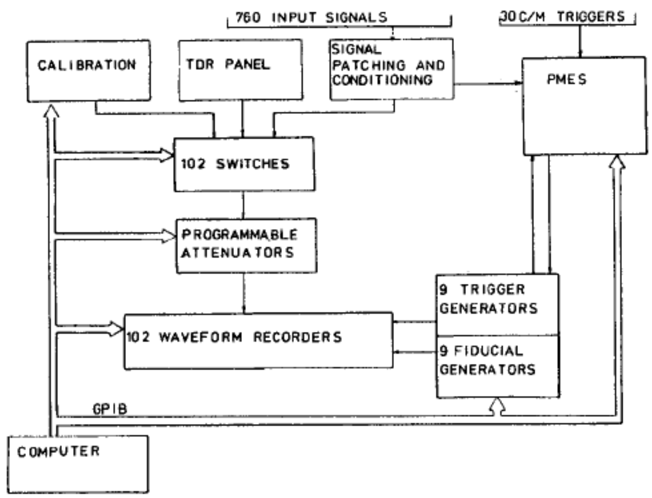

Figure 1. Block diagram of DAS interconnections

A harness was designed to handle the PBFA II signal jumpers from the accelerator to the waveform recorder. One end of each jumper is permanently fixed to the switch input. The cables are next routed through a slack takeup area which separates each cable with fabric to prevent tangling. The free end of the cable feeds through a plastic support panel and is prevented from slipping back by a brass coller (Figure 2). To make a connection, the operator simply pulls the appropriate cable out and connects it to the proper bulkhead feedthru. Conversely, when the cable is disconnected, it slides back into its slot. In this way, any of the 102 waveform recorders can be easily connected to any of the 760 cables which lead to the accelerator.

PMES

The cables and signal conditioning for PMES are hardwired into place. Resistive two way splitters installed in the cable at the input panel allow monitoring of these signals with waveform recorders without affecting the PMES measurement.

Since no switching is incorporated into PMES, all calibrations will require manual patching. The dense packing and large number of data channels in this system create a high potential for cabling errors. To alleviate the problem each cable is marked with its signal name and module number. The cables are also color coded with strips of colored tape near the connector. The color coded cable is matched to a receptacle with a color coded washer. This cabling method allows for verification at a glance.

Trigger and Fiducial Patch Panels

The flexibility and ease of setup of the DAS is dependent on patching of the nine possible trigger delay signals and the nine fiducial time marker signals to the 102 waveform recorders. Unfortunately, cost restraints caused this subsystem to be implemented manually; however, it was designed to provide maximum flexibility, ease, and accuracy of setup within the cost constraints.

In order to provide the maximum flexibility, the worst case scenario of fanning out one trigger and fiducial signal pair to all twenty-two 7912 waveform recorders and 80 LeCroy waveform recorders was considered in the baseline DAS design. Inductive fanouts were used because signal loss is the inverse of the square root of the number of outputs rather than by the number of outputs. Each trigger and fiducial output was connected to a 1 x 8 fanout. The eight outputs allowed four outputs to be routed to any of the eight 7912 1 x 6 fanouts with the other four to be routed to any of the eight LeCroy 1 x 24 fanouts. Thus the four 1 x 6 fanouts produce 24 outputs for the twenty-two 7912's and the four 1 x 24 outputs produce 96 outputs for the 80 LeCroy's. Furthermore, this setup of eight fanouts for both the LeCroy's and 7912's allow eight separate trigger/fiducial pairs to be used for both. Standard off-the-shelf fanout configurations were used to lower costs and all unused outputs are terminated.

The layouts of the fiducial and trigger panels are similar (Figure 3). The first logical division was the 1 x 8 fanout of the nine trigger and fiducial generator outputs along with the input panel to the eight 7912 1 x 6 fanouts and the eight 1 x 24 LeCroy fanouts. The generator outputs and fanout inputs were put between the 7912 section above and the LeCroy section below. The 7912 section above has the inputs to the twenty-two 7912's centered between four 1 x 6 fanouts above and four 1 x 6 fanouts below. The LeCroy section is handled similarly with four 1 x 24 fanouts above

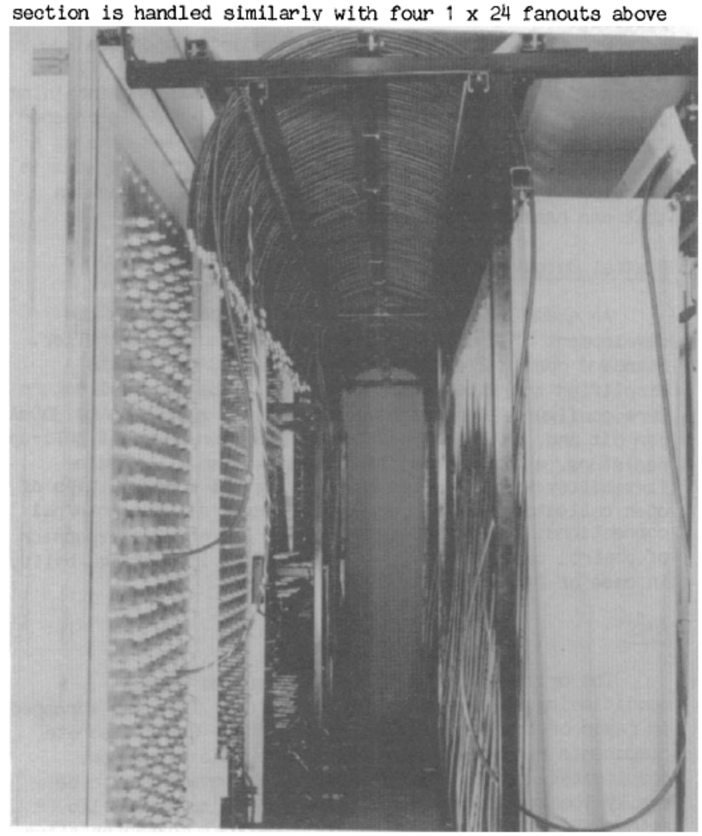

Figure 2. Photograph of signal patch panel and cable harness

and four 1 x 24 fanouts below the 80 inputs to the LeCroy's. The patch cables are fixed at the inputs to the eight 7912's fanouts and eight LeCroy fanouts and also at the twenty-two 7912 inputs and 80 LeCroy inputs. This puts the least number of cables on the panel.

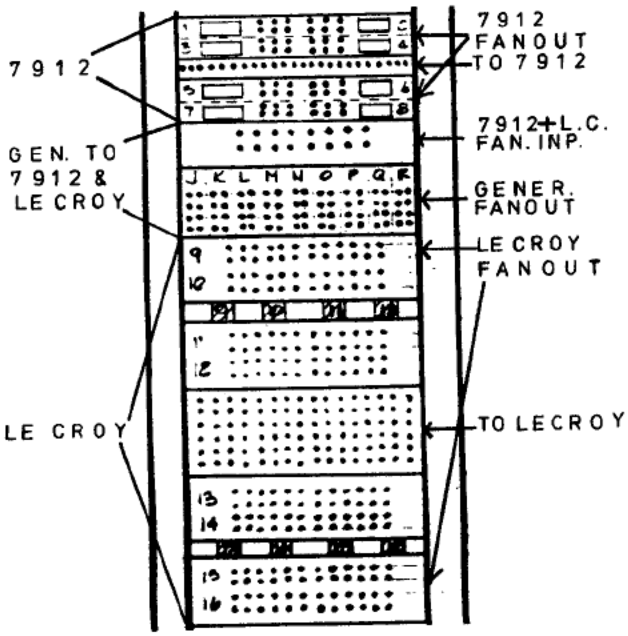

Figure 3. Trigger and fiducial patch panel layout

System Modularity

In order to make the system flexible and maintainable, an effort was made to use modular, commercially available off the shelf equipment and standard components whenever possible.

Off the shelf equipment and standard components provide known performance and proven reliability. System maintenance is also easier and less costly than maintaining a custom built non-modular system. Spare stock is cheaper and interchangeable. Troubleshooting is easier done at a modular level. The challenge to building such a system is in combining existing technologies in a plug-in fashion that can handle several contingencies.

Digital Output Boards

An example of a successful modular design was the development of the CAMAC based open collector controller. Standard open collector components in a CAMAC module simplified the interface to IEEE 488. The open collectors were configured for any external voltage supply up to 300mA per bit and, with the addition of resistor packs of pull-up resistors, a TTL control level was available. Module flexibility was maximized by enabling all possibilities of open collector use with appropriate external and internal connections. The CAMAC based modularity enabled expansion of control capability within a crate and interchangeability in case of failure.

PMES

The original design for PMES required signal conditioning on custom made P.C. boards. This was scrapped in favor of discrete coaxial components. Using discrete components requires more space and makes cabling more complicated, but it also allows faulty components to be easily located and replaced. Separate components also allow PMES to be modified easily if signal characteristics change and increase the isolation between channels.

Facilities

Inadequate DAS cooling and power distribution on PBFA I caused more down time than any other factor. As a result, the design and implementation of these systems on the PBFA II DAS facility is a major concern. The cooling and power must be designed to handle the worst case demand on the DAS rather than an anticipated average operational load.

A major system upgrade of the PBFA II DAS cooling system has been done to provide cooling for the maximum operational load. Such a baseline design approach on PBFA I would have prevented significant down time.

Correct delivery of the cool air to the equipment and removal of the exhaust heat is to be the clue to successful cooling. Simply dumping cool air in the equipment racks is not successful.

Flexible cloth ducting is used on PBFA II to deliver cool air to the temperature sensitive 7912AD and LeCroy waveform recorders. A raised computer floor provides a cool air delivery plenum. The cloth duct is attached to a hole in the computer floor at the bottom of the equipment rack with 750 CFM fans in the holes to pressurize the duct. The other end of the duct is attached to the input fans at the back of the 7912AD waveform recorders. The CAMAC based LeCroy waveform recorders have two duct inputs: one at the power supply and another under the crate. The standard CAMAC crate fans have been removed to maximize air flow thru the crates. The equipment racks have been modified to a provide 4.5" exhaust channel space between racks. The CAMAC based waveform recorders will employ an array of "muffin" fans on the exhaust channel. The use of the ducting, supply fans and exhaust fans have been designed to provide the maximum CFM through the device. The point of the design approach is not to get the devices as cold as possible but to stabilize the temperature of the device as quickly as possible to a very tight (10° maximum) operating temperature range and maintain that range as long as the device is on. Maximizing CFM rather than temperature enables easier operating temperature stability.

Adequate facility power distribution means having enough power available that is also well regulated and conditioned power. The accuracy and reliability of the data devices are dependent on clean power.

Power line variations and noise spikes cause critical waveform recorder components to be operated outside their linear range affecting accuracy. The lifetime of 7912 power supplies is shortened by operating under these conditions. The power supplies fail at higher rates than any single component.

Line variations and noise not only come from the A/C power feed to the room but also from equipment operating in the DAS. The 7912 switching power supplies put significant noise back on the line. In order to address both factors, line conditioning and surge supression must be done at the A/C power input to the equipment along with isolation transformers of each device.

Summary

Improvements in reliability, efficiency and flexibility of the PBFA II DAS have been made. But the task is just beginning. As operational experience with the facility is gained and the program research requirements evolve new inadequacies will be found and new system capabilities must be added.

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